Test and Development Efforts Affecting Systems Engineering Decisions for the AN/AWS-2 Rapid Airborne Mine Clearance System

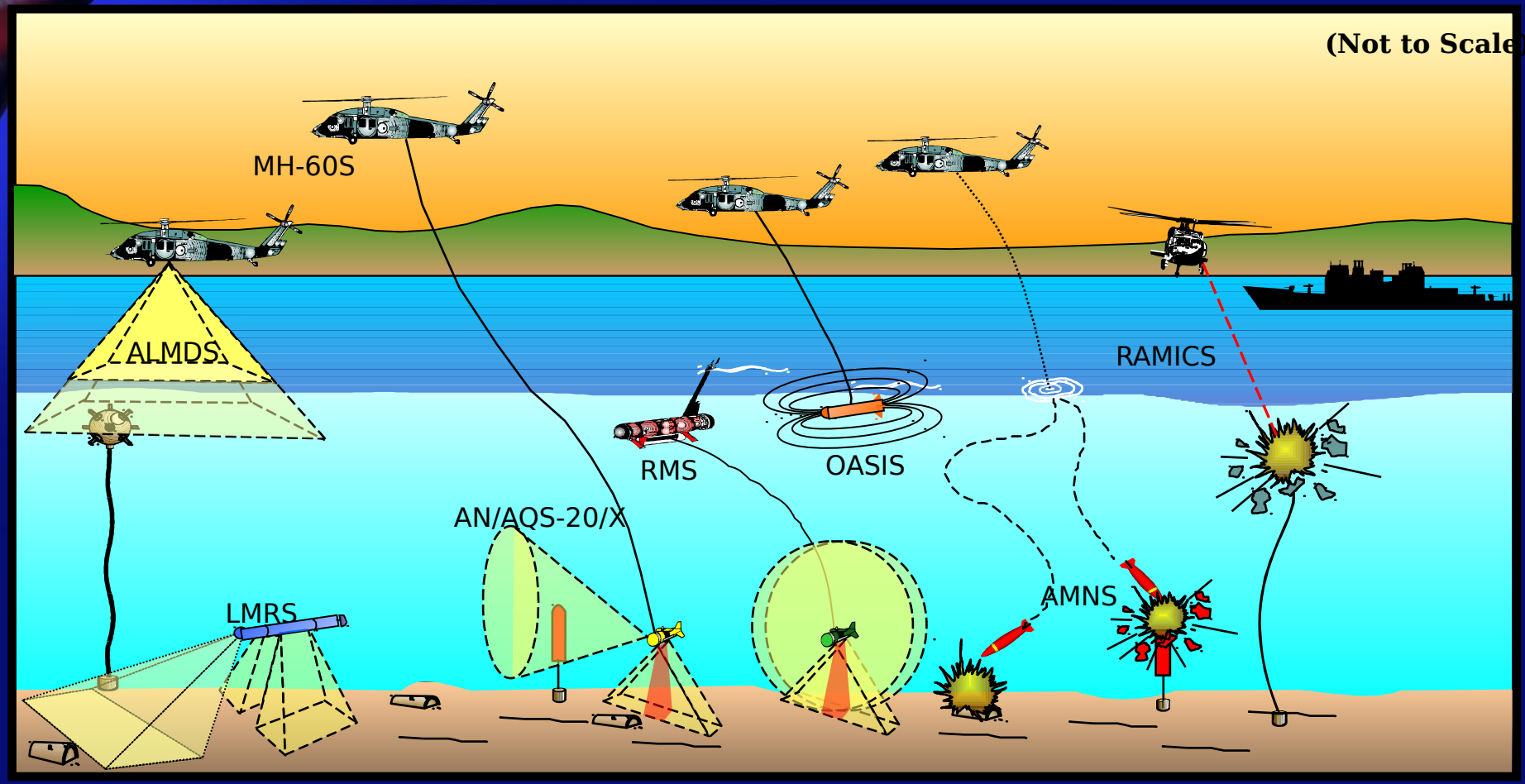
Presented by
Mr. Alan K. Jenkins
to the
6th Annual Systems Engineering Conference
20-23 October 2003

Alan K. Jenkins (4.11.6.2)
Naval Air Warfare Center Aircraft Division
Patuxent River, MD 20670
301-342-1334

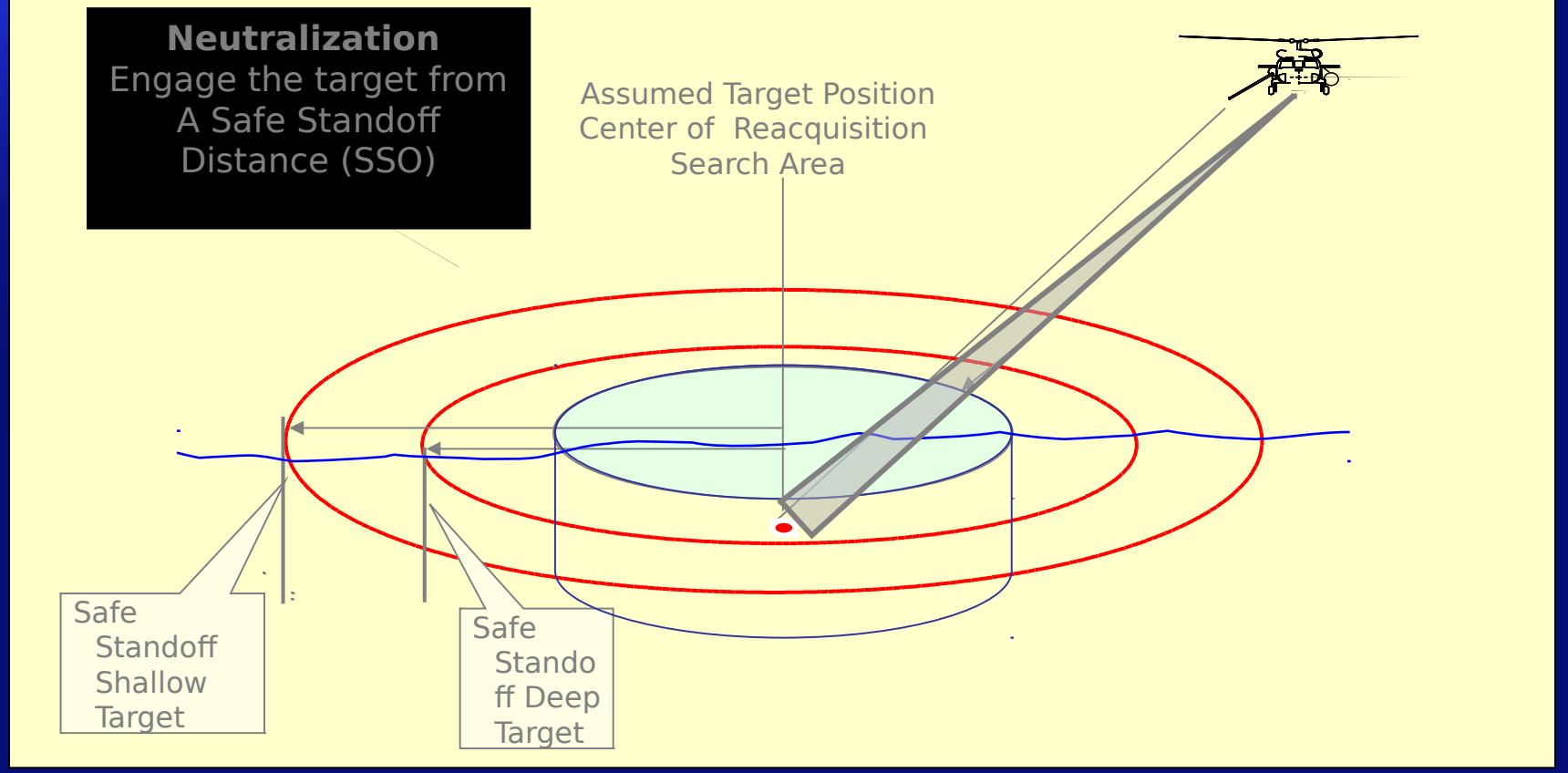
TOPICS

- Organic MCM Concept
- Schedule Challenge
- Approach Taken
- Connection between T&E and SE
  - C&TD
  - SD&D
  - P&D
- Conclusion

THE ORGANIC MCM CONCEPT



RAMICS SYSTEM DESCRIPTION

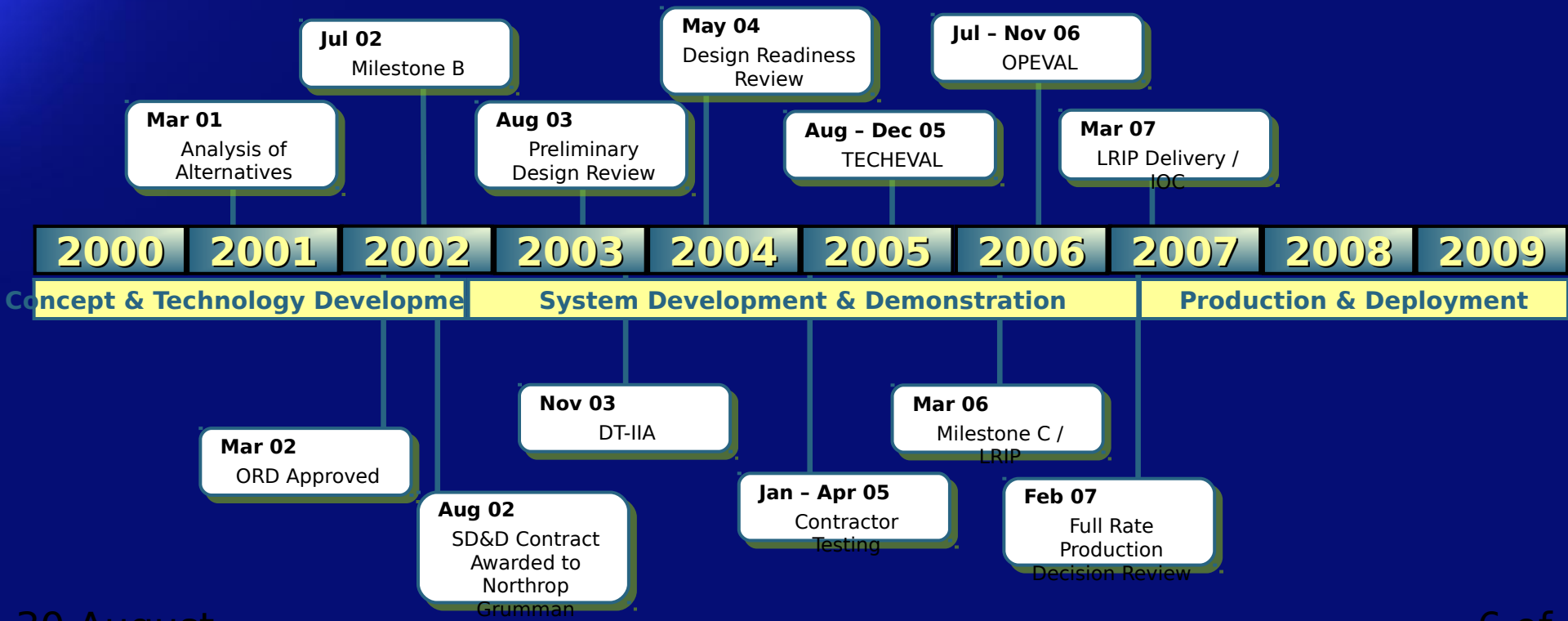


MAIN ISSUES FOR SE

- Munition/Gun Size
  - Based on ORD predictions (ORD signed shortly before MS-B)
- Aircraft Integration
- Targeting System
- Exit Criteria Unknown

RAMICS Program History

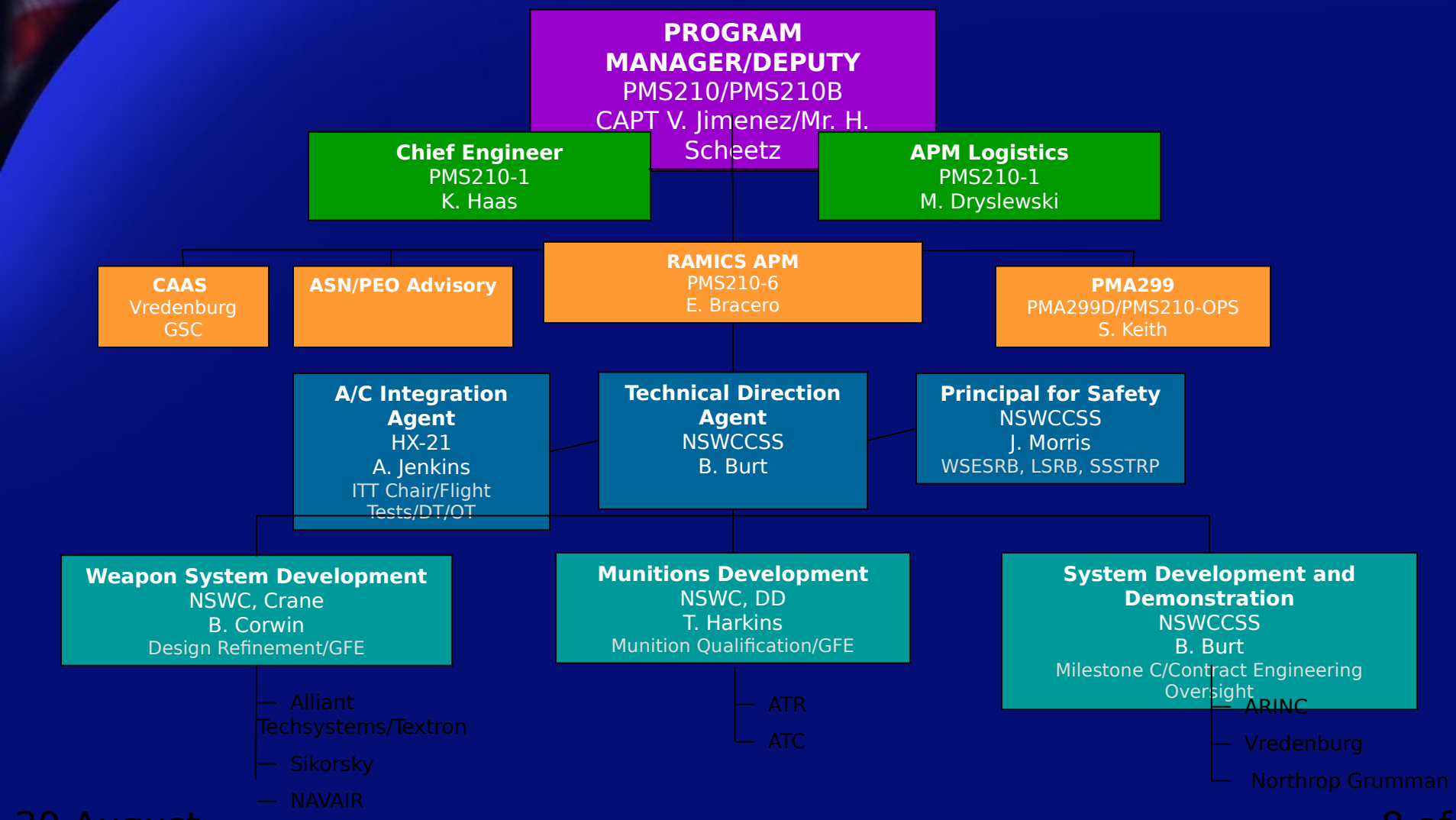
- Accelerated development program to seamlessly insert RAMICS capability into ongoing OAMCM initiative



APPROACH TAKEN

- Parallel Efforts to Keep Risk Low and Minimize Development Schedule
  - Gov't Develop Gun/Munition
    - Begin qualification efforts
    - Collect firing data in flight to support targeting system development and cut risk
  - Contractor Develop Targeting
    - To include integration of entire weapon system

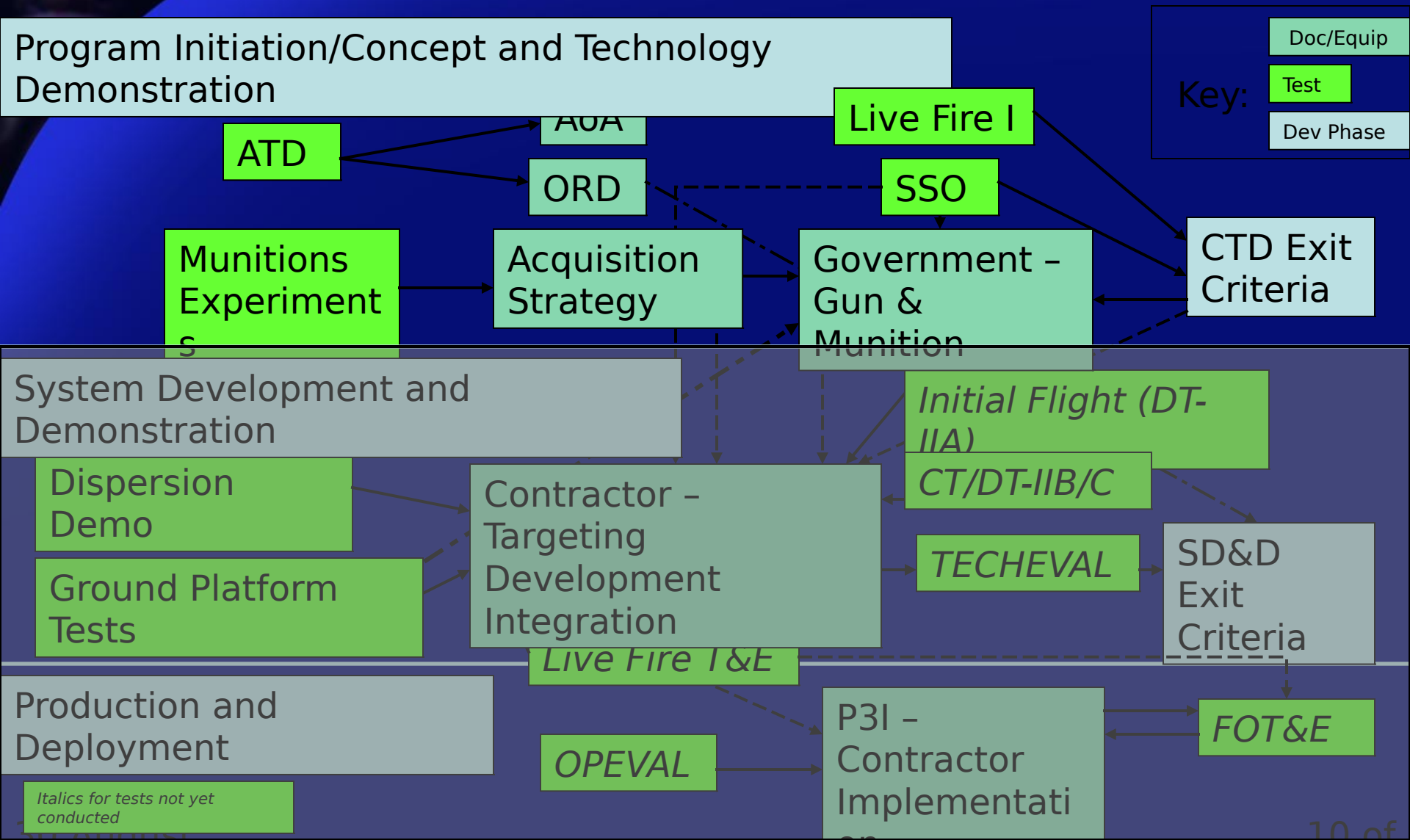
RAMICS
INTEGRATED PRODUCT TEAM (IPT)



KEY C&TD PHASE ISSUES FOR TEST/SE

- AoA Results
  - ATD Underway
  - ORD Input
- Gun/Munition
  - Experiments
- Targeting Performance Specification
  - Pointing Accuracy Needs/Wants
- C&TD Exit Criteria Unknown

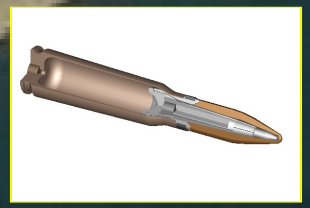
SYSTEMS ENGINEERING FLOW



ADVANCED TECHNOLOGY DEMONSTRATION

AH-1W Cobra

Aircraft MMI Display



RAMICS Munition

Mk6 Mine

MUNITION TESTS

- 20/25/30mm used
- Various nose diameters and shoulder heights/roll offs
- With and without reactive payload
- Successes with 25mm and 30mm
- Munition size drives gun and *visa versa*
- Trade study needed for determination of significant difference

AOA SUMMARY

Gun/Projectile Alternatives – Comparison Matrix

Factor	Alternative (Number)				
	20 mm SS (ATD) w/Reactive M197 (1/2)	25 mm FS w/KE Only M242 (3)	25 mm FS w/Reactive M242 (4)	30 mm FS w/KE Only MK44 (5)	30 mm SS w/Reactive M230 (7)
Relative Performance					
• Deflagration/sinking of near surface mine*	L	M	M	M	L-M
• Deflagration/sinking of 10-15' depth mine	H	H	H	H	H
• Deflagration/sinking of ~30' depth mine	L / L-M	M / H	H	H	L / M
• Deflagration/sinking of 40-60' depth mine	L	L / H	L / H	M / H	L / L-M
• Deflagration/sinking of 70-90' depth mine	L	L / M-H	L	L / H	L
• Rounds required per near surface mine neutralized*	VH	M-H	M-H	M-H	H
• Rounds required per non-near surface mine neutralized	H	L	L	L	L-M
Relative Cost					
• RDT&E	H	L	M	L	H
• Total procurement/O&S	M	M	M	M	M
• Projectile unit cost	H	VL	L-M	L	VH
Relative Risk					
• Technical development risk – projectile	H	L	M	L	H
• Technical development risk – gun/turret	L	L	L	L	L
• Schedule – projectile & gun/turret	Long	Short	Medium	Short	Long
• Development timeline risk – projectile & gun/turret	H	L	M	L	H
Other Factors					
• Munition payload safety	M	H	M	H	M
• Gun integration difficulty	L	M	M	M	M
• Impact on Helo (recoil/loads/etc.)	L	L-M	L-M	M	L
• General adaptability to collateral mission applications	L	H	M	H	L

*At helo safe stand-off ranges (2000-3000')

GUN/MUNITION TRADE STUDY

25 mm vs. 30 mm

- Constructed a Decision Analysis Worksheet described in the Defense Systems Management College (DSMC) System Engineering Management Guide, 1983, Chapter 8 - “Trade Studies.”
  - Provides a disciplined, objective approach to decision making.
  - Applicable in situations where all candidates meet minimum performance requirements.
  - Allows performance parameters to be weighted, scored individually.

TRADE STUDY RESULTS

Parameter	Weight Factor	25mm	30mm
Effective (sink/deflagrate)	Critical	G[1] / R[2]	LB
Integratable	Extremely Important	G	G
Executable	Considerably Important	G	G
Operationally Available	Considerably Important	G	G
Safe	Considerably Important	G	G
Supportable	Considerably Important	G	LB

NOTES:
[1]25mm can sink a mine at the threshold neutralization depth. If sinking is an acceptable neutralization method, then it minimally meets the performance requirement.
[2]25mm cannot deflagrate a mine at the threshold neutralization depth. If a mine must deflagrate in order to be considered neutralized, then the 25mm does not meet the minimum performance requirement.

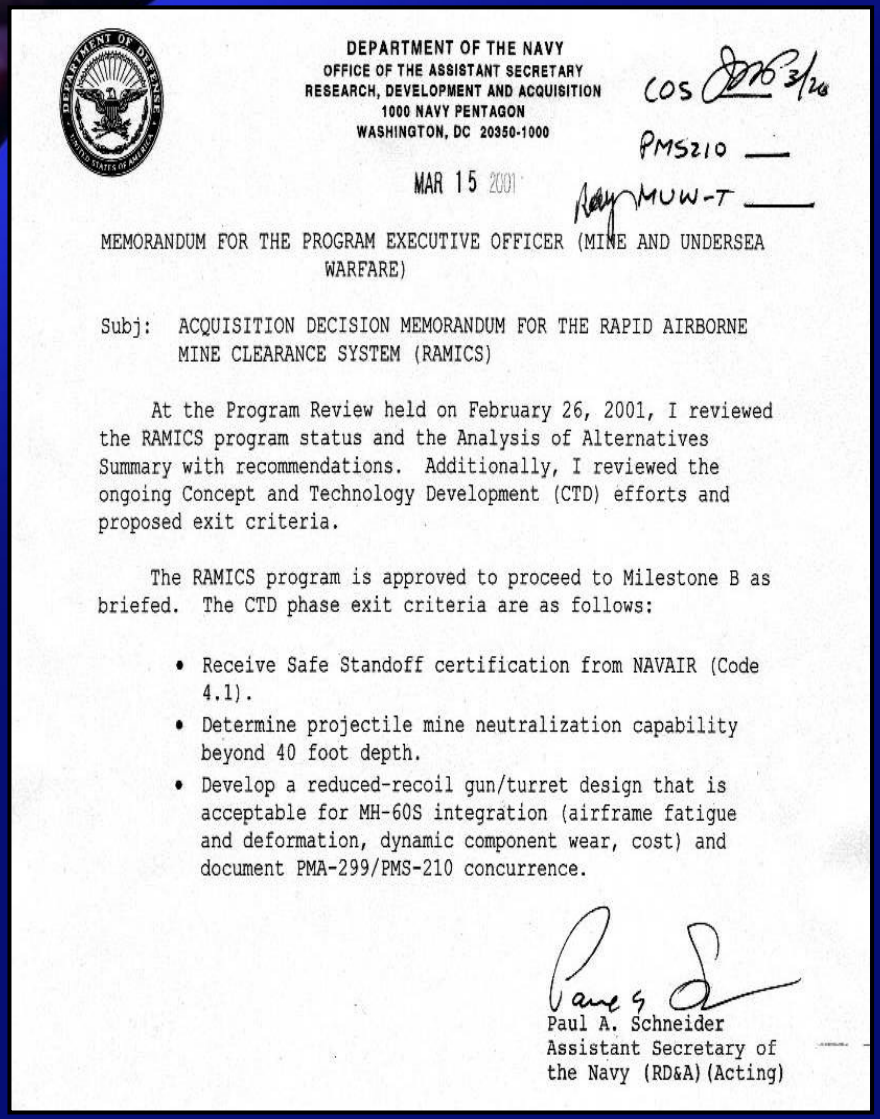
LEGEND

B	Exceeds the requirement
LB	Somewhat exceeds the requirement (objective)
G	Meets the requirement (threshold)
O	Almost meets the requirement
R	Does not meet the requirement

25mm Weight-Score = 152
30mm Weight-Score = 168
Difference = 10.3%

A difference in weight-scores of at least 10% indicates that there is a meaningful distinction between candidates, according to the DSMC SE Management Guide.

CTD PHASE EXIT CRITERIA



DEPARTMENT OF THE NAVY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH, DEVELOPMENT AND ACQUISITION
1000 NAVY PENTAGON
WASHINGTON, DC 20350-1000

COS 3/16
PMS210
MAR 15 2001
MUW-T

MEMORANDUM FOR THE PROGRAM EXECUTIVE OFFICER (MINE AND UNDERSEA WARFARE)

Subj: ACQUISITION DECISION MEMORANDUM FOR THE RAPID AIRBORNE MINE CLEARANCE SYSTEM (RAMICS)

At the Program Review held on February 26, 2001, I reviewed the RAMICS program status and the Analysis of Alternatives Summary with recommendations. Additionally, I reviewed the ongoing Concept and Technology Development (CTD) efforts and proposed exit criteria.

The RAMICS program is approved to proceed to Milestone B as briefed. The CTD phase exit criteria are as follows:

- Receive Safe Standoff certification from NAVAIR (Code 4.1).
- Determine projectile mine neutralization capability beyond 40 foot depth.
- Develop a reduced-recoil gun/turret design that is acceptable for MH-60S integration (airframe fatigue and deformation, dynamic component wear, cost) and document PMA-299/PMS-210 concurrence.

Paul A. Schneider
Assistant Secretary of the Navy (RD&A)(Acting)

ASN RDA Acquisition Decision Memorandum 15 Mar 01 established the following C&TD Phase Exit Criteria :

1. Receive Safe Standoff certification from NAVAIR (Code 4.1).

2. Determine projectile mine neutralization capability beyond 40ft depth.

3. Develop a reduced-recoil gun/turret design that is acceptable for MH-60S integration (based upon airframe fatigue and deformation, dynamic component wear, cost, crash load constraints and other issues as required) and document PMA299/PMS210 concurrence.

Test and Evaluation

Exit criteria completed by testing:

- Safe standoff completed - Jul 02
- Projectile lethality completed - Oct 01
- Reduced recoil conducted - Apr 02

Safe Standoff Tests

- Worst Case Threat
- Ensure Detonation
- Collect Shrapnel Data
- Use Safe Escape Modeling to determine distance for acceptable risk

Distance impacts pointing resolution and accuracy!

CRITERIA #1: SAFE STANDOFF

DEPARTMENT OF THE NAV
NAVAL AIR SYSTEMS COMMAND
RADM WILLIAM A. MOFFETT BUILDING
47123 BUSE ROAD, BLDG 2272
PATUXENT RIVER, MARYLAND 20670-1547

13040
Ser AIR-4.1.8/003
MAY 7 2002

MEMORANDUM

From: AIR-4.1
To: PMA-299

Subj: RAMICS SAFE STANDOFF DISTANCES

Ref: (a) Acquisition Decision Memorandum for RAMICS, 15 March 2001
(b) Rapid Airborne Mine Clearance System Data Package for CTD Phase Exit Criteria #1 Safe Standoff, January 2002
(c) AIR-4.1 1.2 RAMICS Arena Tests Safe Escape Results, draft
(d) AN/AWS-1 Rapid Airborne Mine Clearance System (RAMICS) Safe Standoff Distances Certification, AIR-4.18 memorandum, 16 April 2002

1. The AN/AWS-1 RAMICS consists of a MK44 Bushmaster II 30mm gun and turret subsystem, a lidar targeting/reclassification subsystem, and an operator console integrated into the MH-60S helicopter weapon system. RAMICS is currently in the Concept and Technology Demonstration Phase (phase prior to Milestone B) and is required by reference (a) to "receive Safe Standoff certification from Commander Naval Air Systems Command (COMNAVAIRSYSCOM) (Code 4.1)". Personnel from AIR-4.1.8 and AIR- 4.1.10 were assigned to review references (b) and (c) which document related work during: the RAMICS Advanced Technology Demonstration phase conducted at Patuxent River, Aberdeen Proving Ground, and the Gulf Test Range near Panama City, Florida; the three arena tests in Socorro, New Mexico; and munition performance testing in West Freugh, Scotland. Additional data concerning items such as underwater performance predictions and relevance of targets used the anticipated threats is also contained in reference (b).

2. Personnel from AIR-4.1.8 and AIR-4.1.10 have reviewed references (b) and (c). Based on these references and the analysis documented in reference (d), the recommended safe standoff distances are:
1500 feet for shallow mines
700 feet for deep mines
The safe standoff distance is defined as the horizontal distance measured radially from the center of the mine. The depth is defined as the mean depth from the surface to the top of the mine casing. Training with inert mines/mine shapes can be conducted at the distances noted above or at shorter distances.

Subj: RAMICS SAFE STQNDOFF DISTANCES

3. The RAMICS IPT has been extremely conservative in their analysis regarding hazards to the aircraft and aircrew. While the current data contained in references (b) and (c) can only support the aforementioned distances, additional data would most likely support reduction in these ranges. When additional data and analysis becomes available to support a change in the safe standoff distances, AIR-4.1.8 and AIR-4.1.10 will make recommendations as to the updated distances.

JOHN S. ROSA

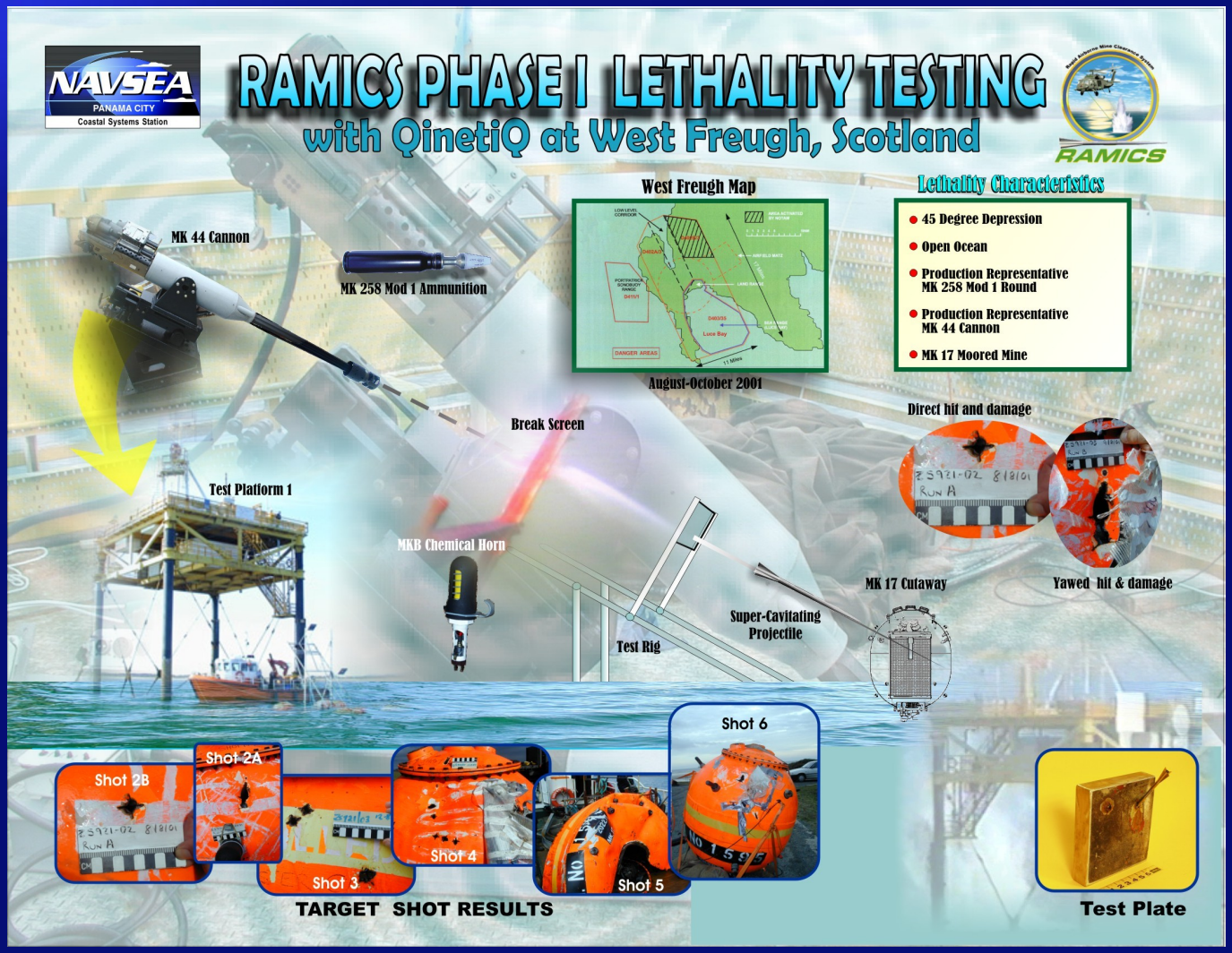
copy to:
AIR-4.1.8
AIR-4.1.10

- Completed - NAVAIR 4.1 certification signed on 7 May 02
- Results : SSO Distances:
  - Shallow mines 1500’
  - Deep mines 700’

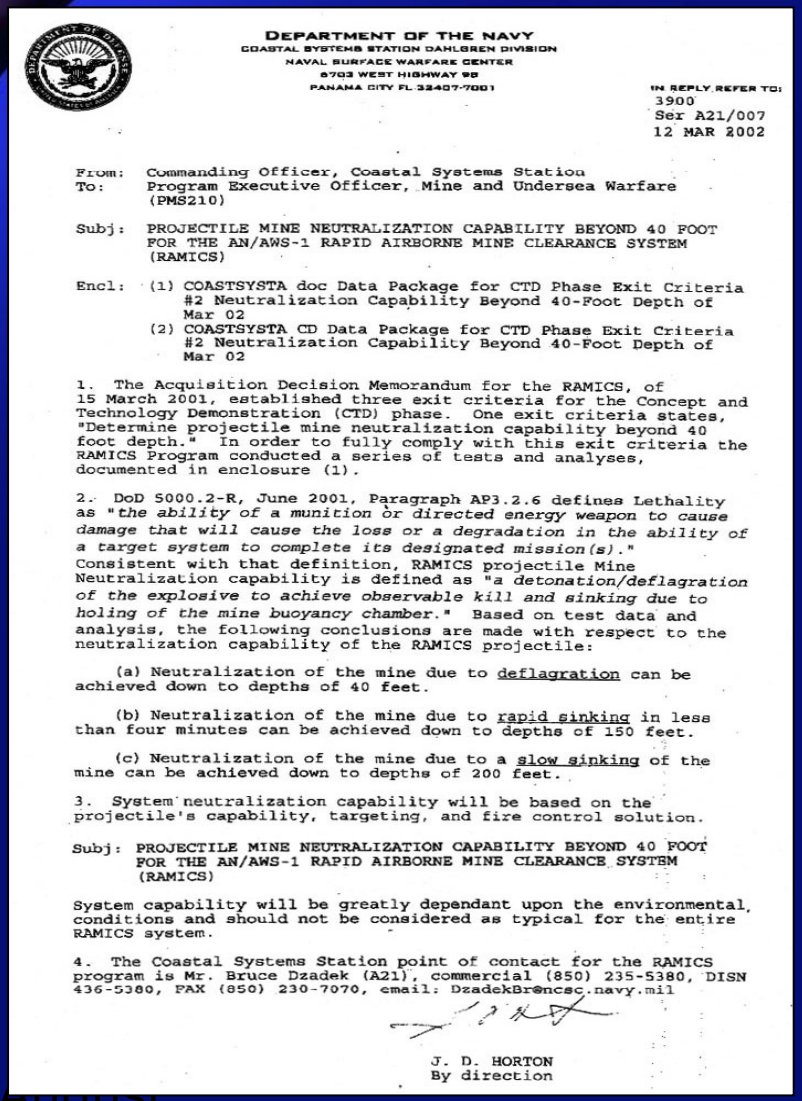
NEUTRALIZATION CAPABILITY

- Conducted at West Freugh, Scotland
- Production Representative Munition
- Live and Inert MK17 Sea Mines
- Simulated Mission Representative Sea Conditions
- Live Fire Test and Evaluation Phase I Tests

WEST FREUGH TESTS



CRITERIA #2: MINE NEUTRALIZATION CAPABILITY BEYOND 40 FT DEPTH



DEPARTMENT OF THE NAVY
COASTAL SYSTEMS STATION DAHLGREN DIVISION
NAVAL SURFACE WARFARE CENTER
6703 WEST HIGHWAY 98
PANAMA CITY FL 32407-7001

IN REPLY REFER TO:
3900
Ser A21/007
12 MAR 2002

From: Commanding Officer, Coastal Systems Station
To: Program Executive Officer, Mine and Undersea Warfare (PMS210)

Subj: PROJECTILE MINE NEUTRALIZATION CAPABILITY BEYOND 40 FOOT FOR THE AN/AWS-1 RAPID AIRBORNE MINE CLEARANCE SYSTEM (RAMICS)

Encl: (1) COASTSYSTA doc Data Package for CTD Phase Exit Criteria #2 Neutralization Capability Beyond 40-Foot Depth of Mar 02
(2) COASTSYSTA CD Data Package for CTD Phase Exit Criteria #2 Neutralization Capability Beyond 40-Foot Depth of Mar 02

1. The Acquisition Decision Memorandum for the RAMICS, of 15 March 2001, established three exit criteria for the Concept and Technology Demonstration (CTD) phase. One exit criteria states, "Determine projectile mine neutralization capability beyond 40 foot depth." In order to fully comply with this exit criteria the RAMICS Program conducted a series of tests and analyses, documented in enclosure (1).

2. DoD 5000.2-R, June 2001, Paragraph AP3.2.6 defines Lethality as "*the ability of a munition or directed energy weapon to cause damage that will cause the loss or a degradation in the ability of a target system to complete its designated mission(s).*" Consistent with that definition, RAMICS projectile Mine Neutralization capability is defined as "*a detonation/deflagration of the explosive to achieve observable kill and sinking due to holing of the mine buoyancy chamber.*" Based on test data and analysis, the following conclusions are made with respect to the neutralization capability of the RAMICS projectile:

(a) Neutralization of the mine due to deflagration can be achieved down to depths of 40 feet.

(b) Neutralization of the mine due to rapid sinking in less than four minutes can be achieved down to depths of 150 feet.

(c) Neutralization of the mine due to a slow sinking of the mine can be achieved down to depths of 200 feet.

3. System neutralization capability will be based on the projectile's capability, targeting, and fire control solution.

Subj: PROJECTILE MINE NEUTRALIZATION CAPABILITY BEYOND 40 FOOT FOR THE AN/AWS-1 RAPID AIRBORNE MINE CLEARANCE SYSTEM (RAMICS)

System capability will be greatly dependant upon the environmental conditions and should not be considered as typical for the entire RAMICS system.

4. The Coastal Systems Station point of contact for the RAMICS program is Mr. Bruce Dzadek (A21), commercial (850) 235-5380, DISN 436-5380, FAX (850) 230-7070, email: DzadekBr@ncsc.navy.mil

J. D. HORTON
By direction

- Completed - Documented in CSS ltr dated 12 Mar 2002
- Results
  - 0 - 40ft Deflagration
  - 40 - 150ft Rapid sinking (less than 4 min.)
  - 150 - 200ft Slow sinking

REDUCED RECOIL DESIGN

- Of the many issues for aircraft integration, at this point RAMICS development, recoil was biggest concern.
- Vendor (Boeing/ATK) must demonstrate recoils consistently under 4000# using training/practice rounds. TP rounds have higher recoil than AP. Objective recoil load is 3000#.

CRITERIA #3: REDUCED RECOIL GUN/TURRET DESIGN

PMA 299/PMS 210 MEMORANDUM OF CONCURRENCE
RAMICS REDUCED-RECOIL GUN/TURRET DESIGN
CONCEPT AND TECHNOLOGY DEMONSTRATION PHASE EXIT CRITERIA

1. Purpose: The purpose of this Memorandum of Concurrence (MOC) is to document PMA-299 and PMS-210 concurrence on the Rapid Airborne Mine Clearance System Exit Criteria #3.

2. Background: The Acquisition Decision Memorandum for the Rapid Airborne Mine Clearance System (RAMICS), dated 15 March 2001, establishes three Exit Criteria for the Concept and Technology Demonstration (CTD) phase. Exit Criteria #3 states, "Develop a reduced-recoil gun/turret design that is acceptable for MH-60S integration (airframe fatigue and deformation, dynamic component wear, cost) and documented PMA-299/PMS-210 concurrence".

3. During the CTD phase, a reduced recoil gun subsystem design has been completed that reduced gun recoil from 10,000 lbs to under 4,000 lbs. Based on the current test data at this phase of the RAMICS program, PMA-299, and PMS-210 concur that the reduced recoil design for the gun/turret sub-system is acceptable for MH-60S integration. Additional analysis and testing is required to determine other impacts on the aircraft in the DT-IIA configuration (flying qualities/handling, engines, electronic components, dynamic components, system safety, and human factors, as well as follow-on fatigue and crash load analysis) as part of the integration effort.

09MAY02
CDR W. J. Fulton (Date)
PMA-299 MH-60S IPT Lead

9May02
K. W. Haas (Date)
PMS-210 IPT Lead

Completed – PMS-210/PMA-299 concurrence signed on 9 May 02

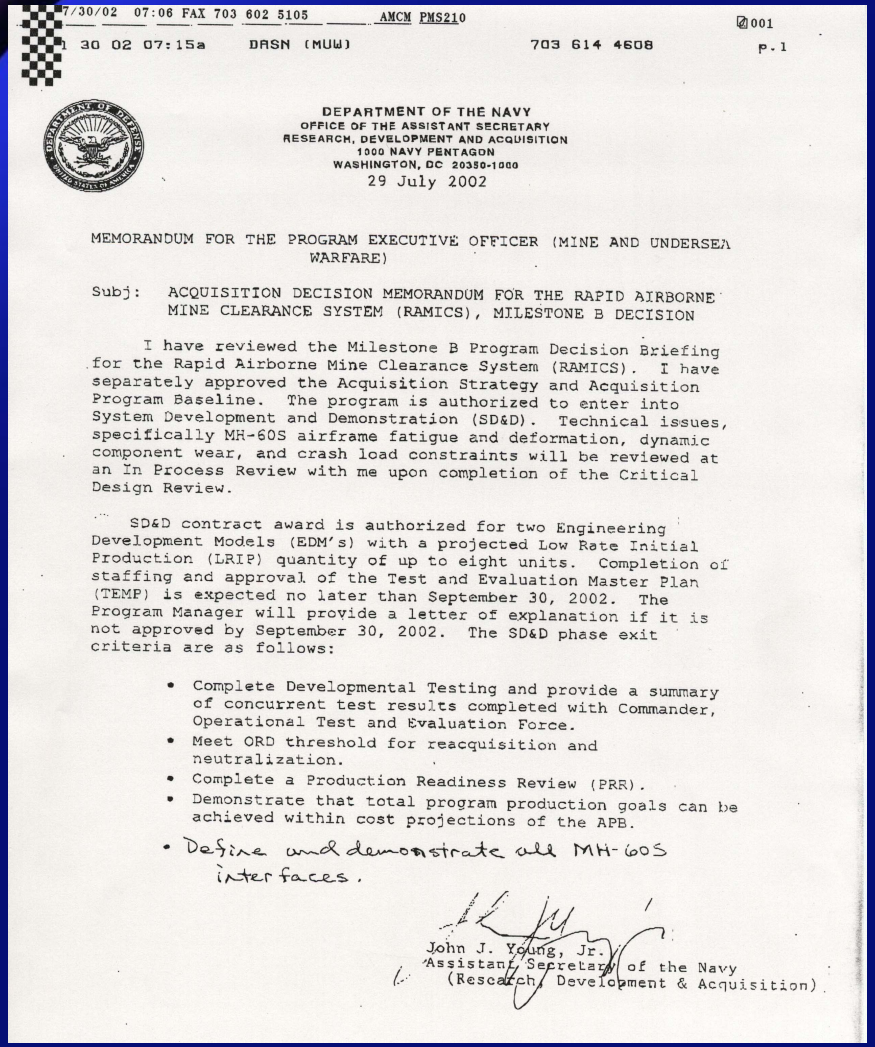
Results

Achieved recoil reduction below 4000lbs for armor piercing and Target Practice rounds

C&TD SYNOPSIS

- ATD program provided AoA and ORD inputs/program justification
- Munitions experiments/tests fed trade study to determine if significant difference between 25mm and 30mm. Munition size drove gun decision.
- SSO test results provided limits for targeting specification and exit criteria
- Live Fire Phase I results provided exit criterion and verified analysis/reduced program risk.
- SD&D Exit Criteria set at C&TD completion

SD&D PHASE EXIT CRITERIA



7/30/02 07:06 FAX 703 602 5105 AMCM PMS210 001

1 30 02 07:15a DASN (MUW) 703 614 4608 p.1

DEPARTMENT OF THE NAVY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH, DEVELOPMENT AND ACQUISITION
1000 NAVY PENTAGON
WASHINGTON, DC 20350-1000

29 July 2002

MEMORANDUM FOR THE PROGRAM EXECUTIVE OFFICER (MINE AND UNDERSEA WARFARE)

Subj: ACQUISITION DECISION MEMORANDUM FOR THE RAPID AIRBORNE MINE CLEARANCE SYSTEM (RAMICS), MILESTONE B DECISION

I have reviewed the Milestone B Program Decision Briefing for the Rapid Airborne Mine Clearance System (RAMICS). I have separately approved the Acquisition Strategy and Acquisition Program Baseline. The program is authorized to enter into System Development and Demonstration (SD&D). Technical issues, specifically MH-60S airframe fatigue and deformation, dynamic component wear, and crash load constraints will be reviewed at an In Process Review with me upon completion of the Critical Design Review.

SD&D contract award is authorized for two Engineering Development Models (EDM's) with a projected Low Rate Initial Production (LRIP) quantity of up to eight units. Completion of staffing and approval of the Test and Evaluation Master Plan (TEMP) is expected no later than September 30, 2002. The Program Manager will provide a letter of explanation if it is not approved by September 30, 2002. The SD&D phase exit criteria are as follows:

- Complete Developmental Testing and provide a summary of concurrent test results completed with Commander, Operational Test and Evaluation Force.
- Meet ORD threshold for reacquisition and neutralization.
- Complete a Production Readiness Review (PRR).
- Demonstrate that total program production goals can be achieved within cost projections of the APB.
- Define and demonstrate all MH-60S interfaces.

John J. Young, Jr.
Assistant Secretary of the Navy
(Research, Development & Acquisition)

ASN RDA Acquisition Decision Memorandum
29 Jul 02 established the following SD&D Phase Exit Criteria :

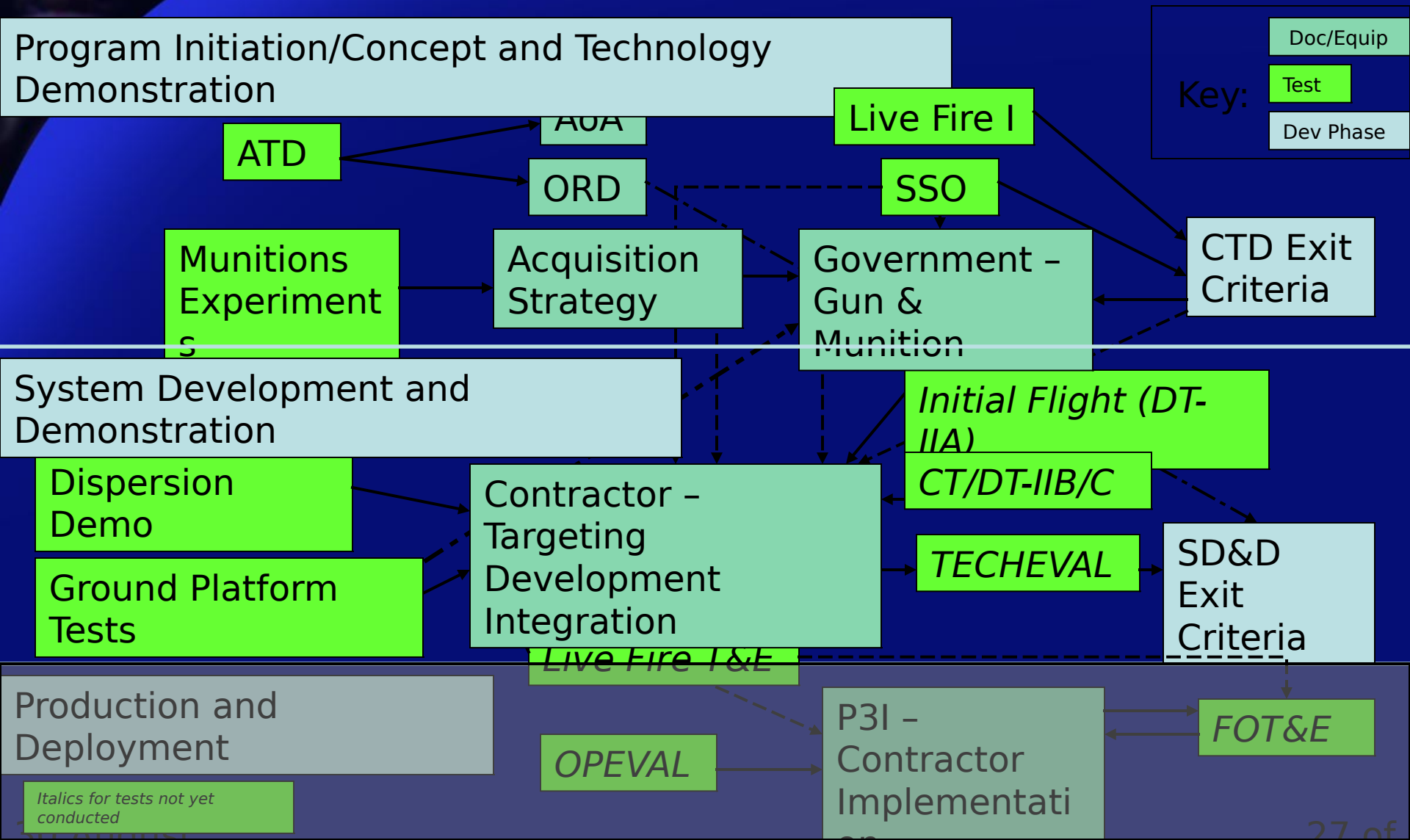
1. Complete Developmental Testing and provide a summary of concurrent test results completed with Commander, Operational Test and Evaluation Force.
2. Meet ORD threshold for reacquisition and neutralization.
3. Complete a Production Readiness Review.
4. Demonstrate that the total program production goals can be achieved within cost projections of the APB.
5. Define and demonstrate all MH-60S interfaces.

KEY SD&D TESTS

- Dispersion Demo
- Ground Platform
- *DT-IIA, Initial Flight Tests*
- *DT-IIB/CT/DT-IIC, Contractor Tests and prep for TECHEVAL*
- *TECHEVAL*

Tests in italics have yet to be performed.

SYSTEMS ENGINEERING FLOW

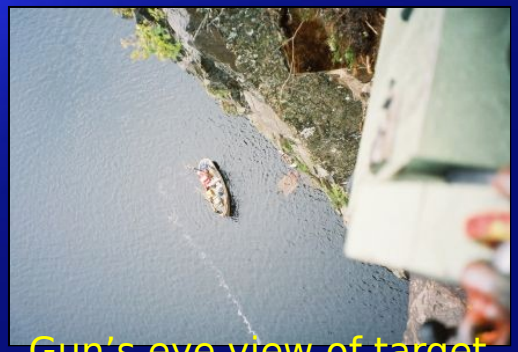


RAMICS SD&D DESIGN CONCEPT

Dispersion Demonstration

- Conducted by Raufoss (MK 258 manufacturer) at Snillfjord, Norway. MK258 Mod 1 cartridges were used against a test plate.
- Water depths up to 75 feet with in air travel of approximately 300 feet. Gun alignment was slightly modified between series of shots (7 in a series) to get grouping data. Single shots only.
- Quick look results indicate dispersion very tight at depth. Final report in review at CSS.

DISPERSION DEMONSTRATION



Gun's eye view of target plate.

Target plate is 1 meter square

Two groupings shown. Each grouping fits within approximately 6" circle

GROUND PLATFORM TESTS

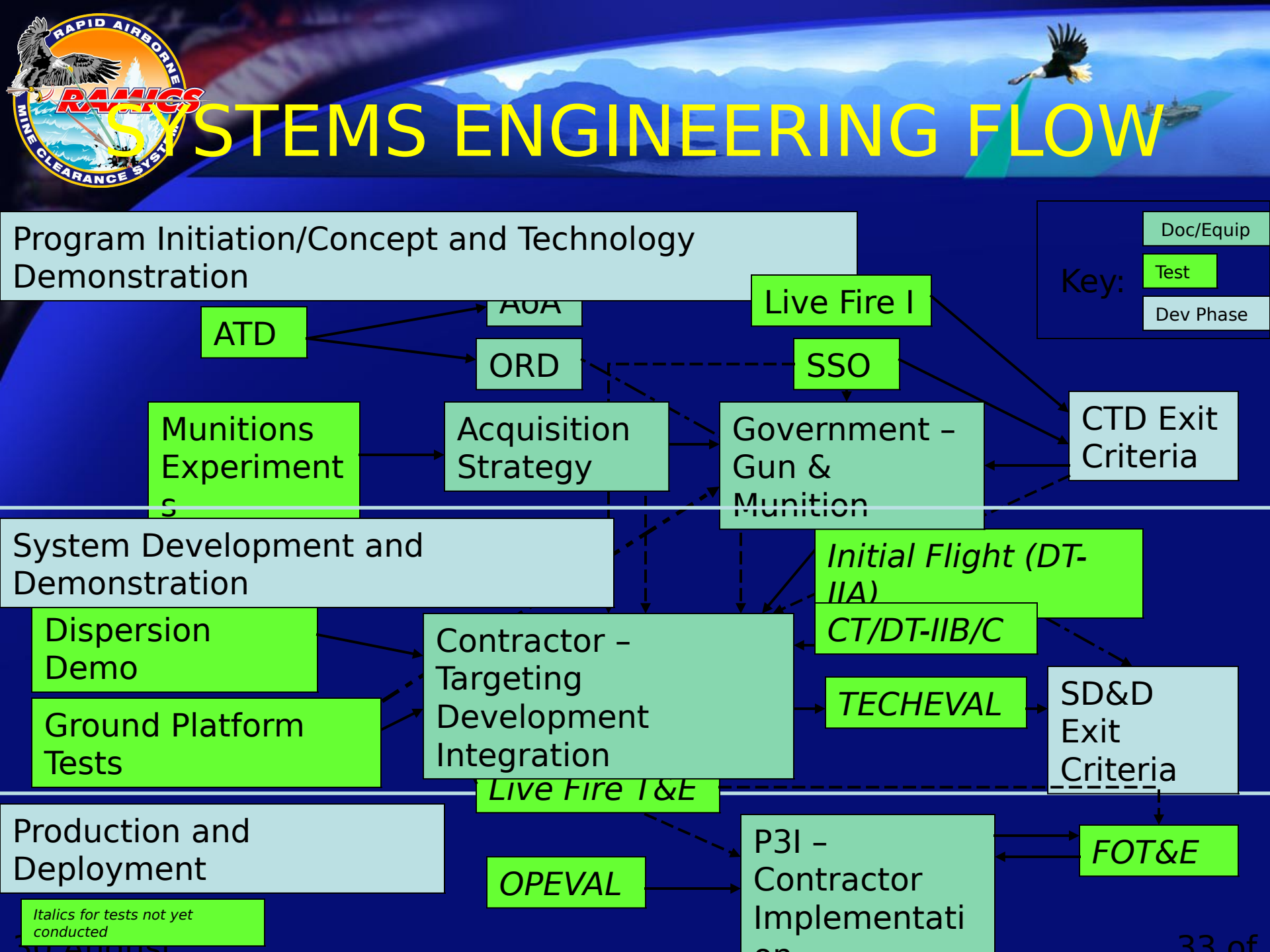
- Conducted at Eglin AFB with DT-IIA Flight Configuration Hardware (gun and munition)
- Collected data at various azimuth/depression angles
- Data used to predict aircraft AND targeting pod effects of recoil

GROUND PLATFORM TESTS

Right – Front view of test setup

Left – Side view of equipment tested. This is the DT-IIA equipment to be flown

SYSTEMS ENGINEERING FLOW



FUTURE TESTING

- DT-IIA – In-flight data used for more accurate estimate of production configuration responses
- CT/DT-IIB/DT-IIC – Tests at increasingly system maturity levels
- TECHEVAL/LFT&E – Production Representative configurations, data for P3I efforts
- OPEVAL/FOT&E – Final check, data used for P3I efforts

DT-IIA Configuration

RAMICS gun subsystem prototype installed on an MH-60S helicopter. Note the final design has the gun installed on the starboard side of the aircraft.

CONCLUSION

- By introducing T&E at beginning of the Systems Engineering process, several real benefits were realized:
  - Kept/Keeps Risk Manageable
  - Saved Time (e.g., splitting responsibilities)
  - Avoided Costs (e.g., munition development)
  - Early Documentation
  - Keeps Team Focused on Finish Line
- Key was complete buy-in and participation by engineering and test experts – borderless team. Especially challenging given wide geographic area and diverse community (Sea and Air sides)

Questions?